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In response to the 1990 Clean Air Act Amendments, DOD and USAF policy, the Environment Systems Division of the Human Systems Program Office, Human Systems Center, Brooks AFB TX has developed a program to systematically eliminate references to particularly active Class I Ozone Depleting Chemicals (ODC) from gas turbine engine technical data. Additionally, Executive Order 12856 and subsequent DOD directives drive the reduction in volume usage of Environmental Protection Agency (EPA) 17 toxins. Program scope includes the validation of requirements for usage, examination of commercially available alternatives, identification of solutions implemented by manufacturers, and qualification of potential alternatives where necessary. Technical and management approaches are discussed.

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ODC/EPA 17 Elimination from DOD Technical Data and Gas Turbine Engines

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1. INTRODUCTION

The 1990 Clean Air Act Amendments restrict the production of Ozone Depleting Chemicals (ODCs), with emphasis on particularly active Class I ODCs. These amendments require the elimination of Class I ODC production by 1 January 1996. Additionally, Executive Order 12856 and Department of Defense goals drive the reduction of Environmental Protection Agency (EPA) 17 usage. The FY '93 National Defense Authorization Act prohibits the award of new contracts after 1 January 1993, if the contract requires the use of a Class I ODC. The Undersecretary of the Air Force for acquisition policy requires the Air Force to eliminate the use of Class I ODCs. However, Air Force technical data (including technical orders (T.O.s), specifications, and standards) currently mandate the use of ODCs, and EPA 17 chemicals.

The Environmental Systems Division of Air Force Materiel Command's Human Systems Center has contracted, through the U.S. Army, with the National Defense Center for Environmental Excellence (NDCEE), operated by Concurrent Technologies Corporation (*CTC*) to conduct a program dedicated to the elimination of Class I ODC references from turbine engine technical data. A secondary goal of the program is to reduce the usage of industrial toxins targeted in the EPA 17 list. Successful conclusion of this program results in compliant weapon system operation and sustainment at Department of Defense (DoD) depots. Program scope includes the systematic review of all affected T.O.s, with the development of application-specific performance requirements for identified Class I ODCs and targeted EPA 17 chemical references. Once requirements are understood, commercially available alternatives to identified targeted substances are investigated and qualified, or if none are available, new processes are developed and validated. Upon government acceptance of recommended alternatives, changes to T.O.s are initiated for the affected weapon system. The initial work effort focused on elimination of ODC callouts from TF39 turbine engine T.O.s and will be the subject of this paper. The collaborative efforts of the U.S turbine engine manufacturers and the DoD have led to an unprecedented sharing of data in pursuit of a common goal.

2. APPROACH

The Management and Technical Approaches for the TF39 effort are addressed below.

2.1 Management Approach

Propulsion Environmental Working Group

Propulsion professionals have been collaborating for several years through a forum called the Propulsion Environmental Working Group (PEWG). This group was organized to share technical information in pursuit of environmentally acceptable substitutes for use in the manufacture and repair of gas turbine engines. Representatives from Allison, General Electric (GE), Pratt & Whitney (P&W), Allied Signal, Williams International and the Aerospace Industries Association participate in the PEWG along with DoD members from the USAF, Army, and Navy.

Integrated Product Team

The effort began with the formation of an Integrated Product Team (IPT). The team is managed by the Weapon Systems Pollution Prevention IPT at the Human Systems Center, Brooks AFB, TX, with members from the Life Cycle Environmental Center at Picatinny Arsenal, NJ and the Propulsion Directorate of the San Antonio Air Logistics Center at Kelly AFB, TX. The NDCEE, operated by *CTC*, as the prime contractor for the effort to eliminate Class I ODC references and reduce EPA 17 references from turbine engine technical data, also has an integral role in the IPT. The IPT for subsequent engine efforts will contain a member from the USAF organization with engineering authority for that engine's technical data. This ensures that engine-specific concerns and depot issues are adequately addressed and ultimately translates to the expeditious approval and implementation of recommended alternatives. The IPT benefits from the counsel and industry-wide developments identified by the PEWG. This forum has provided a unique platform for integration of environmentally compliant solutions between turbine engine manufacturers and DoD sustainment activities.

Alternative Material Selection Responsibilities

The program's philosophy includes the establishment of subcontractual relationships between NDCEE (*CTC*) and the original equipment manufacturers (OEM) for pursuit of alternatives. Proposed alternatives are then reviewed by *CTC* and forwarded to the USAF IPT for approval and implementation. This approach provides safeguards against adverse impact to system performance and life cycle cost. For production engines, warranty issues are also a consideration in the selection of alternatives.

Demonstration/Validation Responsibilities

The NDCEE factory demonstration facilities in Johnstown, PA, operated by *CTC* , will be used to evaluate alternatives. This approach mitigates risk to ongoing government depot operations and production schedules, while "proving" new products and processes. Test data from previously conducted efforts is reviewed and used to the maximum extent possible, further reducing both risk and associated program costs.

Information Exchange

Through periodic meetings of the PEWG, turbine engine manufacturers are afforded the opportunity to review suggested alternatives and potentially incorporate them for use in technical data governing their products. To maximize the availability and utility of this data, a database

written in Microsoft Access has been developed, with NDCEE (*CTC)* serving as the custodian. The data is accessible to users either on disk or through electronic transfer. In many instances, pollution prevention solutions identified for one engine may be equally suited for use on other engines. Strong information exchange capabilities reduce redundancy of effort and result in economies of scale in the qualification of solutions.

2.2. Technical Approach

The USAF, in conjunction with *CTC* and its subcontractors, systematically reviewed selected T.O.s, identified both ODC and EPA 17 references, and provided alternative materials for processes and procedures. Steps in the process included:

1. Screen technical data to generate a Chemical Process List (CPL) which identifies references to regulated substances. Screening is conducted by the USAF, with CPLs provided to *CTC*. The OEM and *CTC* verify the data in the CPLs through a cross-check against referenced T.O.s. Instances in which the T.O. contains an approved alternative are reported to the government.

2. Establish the performance requirements for each T.O. reference to a Class I ODC or EPA 17 substance. This step provides an understanding of how and why each substance is used.

3. Evaluate existing OEM or commercial alternatives against the performance requirements. When sufficient data exists for a qualification decision, direct substitution is possible.

4. Prepare test and evaluation program plan and conduct required testing. When data gaps exist for a qualification decision, a test plan is developed for government-approval. The approved test and evaluation plan is then used to govern the conduct and reporting of *CTC*'s qualification effort.

5. Identify Research & Development (R&D) opportunities. If candidate alternatives prove unsuccessful in the qualification effort, then the requirement is identified for further R&D.

3. RESULTS OF TF39 ODC ELIMINATION

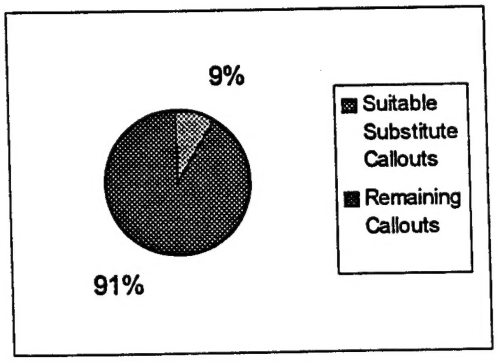
Screen Technical Data

GE personnel reviewed the government-furnished CPLs, dated 1993, and GE's internal database to identify all materials used during engine manufacture with Class I ODC constituents. The resultant list of ODC-containing constituents was searched electronically. Manual search of the latest revisions to T.O.2J-TF39-3 and T.O.2J-TF39-6 were conducted. Since 1993, many of the affected T.O.s had undergone revision through their normal revision cycle. Thus, the combined electronic/manual search yielded improved accuracy over the electronically prepared CPLs dated 1993.

Of the 179 Class I ODC callouts identified, nine percent, or 17, contained a T.O. approved alternative (Figure 1). The "suitable" substitutes documented in the T.O. were reviewed for applicability. Table 1 summarizes processes and T.O. approved substitutes.

As noted in the table, perchloroethylene, an EPA 17 chemical, was deemed the most

Figure 1: Nine percent of the callouts for ODCs identified an alternative in the T.O.



suitable T.O. approved substitute in four instances. The priority for the initial TF39 work was the elimination of Class I ODCs. Replacements for perchloroethylene will be considered only after all ODCs have been addressed.

Callout Substance	Process (occurrences)	T.O. Approved Substitute(s)
1,1,1 TCA	vapor degrease (1)	perchloroethylene
1,1,1 TCA	wipe clean (5)	isopropyl alcohol, acetone, alcohol
1,1,1 TCA	ultrasonic clean (1)	perchloroethylene
1,1,1 TCA	immerse clean (2)	perchloroethylene
1,1,1 TCA	clean to prime (1)	acetone
1,1,1 TCA	clean for adhesive (1)	detergent
1,1,1 TCA	clean for resin (1)	isopropyl alcohol
1,1,1 TCA	fluorescent penetrant inspection (1)	acetone
Freon	flush clean (1)	isopropyl alcohol
Freon	fill clean (1)	isopropyl alcohol
Freon	ultrasonic cleaning (1)	PD-680
MS-143	release agent (1)	RAM 225

Table 1: TO Approved (Non-ODC) Substitutes

Establish Performance Requirements

The incorporation of alternative materials in technical data used in weapon system sustainment operations requires an understanding of each hazardous material's use. This understanding preserves both system integrity and safety considerations. Each callout of a Class I ODC was investigated to identify both the process(es) preceding the callout and the required post-treatment processing. Knowledge of prior processing assisted material/process engineers in the selection of alternatives by providing information on which residual contaminants could be expected. Post ODC process information provided data on "how clean" the part needed to be for the next process. In some cases, engineering assessment resulted in the elimination of a step currently requiring the use of an ODC.

Table 2 shows representative segments of data available in the Microsoft Access database for use in the requirements definition process.

Table 2 - Example of Database Report on Performance Requirements

Technical Order: 2J-TF39-3 **Work Package:** 045 00 **Stage 1 Fan Stator Module - Cleaning, Inspection and Repair**

Page/ Par./ Step	ParagraphTitle	ODC Tradename/ ODC Constituent/ Physical State/ CASNumber	Current Process	Process Objective	Previous Process/ Next Process	Part Name/ Substrate/ Specification	Coating Name/ Specification	Comments
108 41 j(1)	Replacement of Bolts And Bushings in Fan Stator Outer Vane Spacers and Shroud Segment	MS-143 RELEASE AGENT 1,1,1 TRICHLOROETHANE LIQUID 71-55-6	APPLICATION OF RELEASE AGENT	PREPARE REPAIR FIXTURE SURFACE	PREPARE EPOXY ADHESIVE CURE ADHESIVE	Fan Stator Outer Vane Spacers PLASTIC COMPOSITE NA	NA NA	Proposed alternative contains a Class II ODC (HCFC 141b)
110 43 l	Repair of Damaged Edges on Fan Stator Vane Spacers and Shroud Segments	MS-122 or MS-143 RELEASE AGENT 1,1,1 TRICHLOROETHANE LIQUID 71-55-6	APPLICATION OF RELEASE AGENT	PREPARE REPAIR FIXTURE SURFACE	DEGREASE SURFACE APPLY ADHESIVE	Fan Stator Vane Spacers And Shroud ALUMINUM NA	NA NA	Proposed alternative contains a Class II ODC (HCFC 141b)
18 9 h	Replacement of Abradable Seal Material on Stage 1 Fan Stator Case	CHLOROTHENE 1,1,1 TRICHLOROETHANE LIQUID 71-55-6	CLEAN (WIPE)	CLEAN PRIOR TO APPLYING EPOXY RESIN	GRIT BLAST CASE SURFACE APPLY EPOXY SEAL COMPOUND	Stage 1 Fan Stator Case ALUMINUM AMS 425	NA NA	
19 9 o	Replacement of Abradable Seal Material on Stage 1 Fan Stator Case	CHLOROTHENE 1,1,1 TRICHLOROETHANE LIQUID 71-55-6	CLEAN (WIPE)	CLEAN AFTER EPOXY RESIN APPLICATION	APPLY EPOXY RESIN CURE EPOXY RESIN	Stage 1 Fan Case ALUMINUM AMS 425	NA NA	
3 4 NA	Consumable Material	CHLOROTHENE 1,1,1 TRICHLOROETHANE LIQUID 71-55-6	CONSUMABLE LISTING	NA	NA NA	NA NA NA	NA NA	

A few noteworthy recommendations resulted from the TF39 engine effort. Among them was the general avoidance of Terpene-based cleaners in an effort to minimize additional rinse process steps required to avoid residues.

Methyl Ethyl Ketone (MEK) is often an acceptable alternative material from material and process compatibility perspectives. However, as an EPA 17 chemical, MEK should be avoided whenever possible. In the TF39 effort, MEK was recommended only when no proven alternative was available.

Evaluate Existing Alternatives

Significant effort expended in the search for ODC alternatives. *CTC* has been validating the effectiveness of power spray washers, ultrasonics, aqueous cleaning chemistry and other alternatives. The gas turbine industry is conducting similar test programs and continues to implement changes to the overhead/repair procedures used for commercial engines. The air logistic centers have also been proactive, many making capital investments to facilitate a transition to aqueous-based cleaning as an alternative to Class I ODC usage. The current challenge is to expand the use of recently proven alternatives to all DoD components and agencies.

For most TF39 Class I ODC callouts, an OEM approved alternative was readily identified. This substantiated the belief that DoD OEMs have already eliminated the use of Class I ODCs in their manufacturing processes. Each GE-approved alternative was reviewed by *CTC*. Approved alternatives, along with exact verbiage for required T.O. changes, were entered into the Microsoft Access database. The database was then used to generate a comprehensive report and the AFMC Form 252, "T.O. Publication Change Request." Selected replacements were evaluated and qualified by the OEM through experience and proven product performance in similar applications. Other potential processes and products may exist, but additional time and testing are required.

4. CONCLUSIONS

Substitutes were identified for all Class I ODCs called out in TF39 turbine engine T.O.s The program team continues work under this contract to find a substitute for Perchlorethylene in vapor degreasing.

The program team collaborated to produce AFMC Forms 252 and Operational Supplements as recommendations for change. The government is currently processing AFMC Forms 252 to render TF39 engine T.O.s "ODC free" in compliance with Air Force directives and policy.